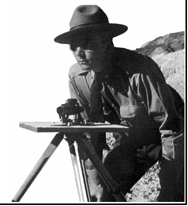
GEOLOGIC RESOURCE MONITORING PARAMETERS

Surface Displacement



Brief Description: In many regions the Earth's surface in many regions is subject to small but important displacements (uplift, subsidence, lateral movement, rotation, distortion, dilation) that affect elevation and horizontal position. These movements result from active tectonic processes within the Earth, collapse into underground cavities, or the compaction of surficial materials. Sudden movements may be caused by faulting associated with earthquakes [see seismicity], and from the collapse of rock or sediment into natural holes in soluble rocks (e.g. salt, gypsum, limestone [see karst activity]), or into cavities produced by mining of near-surface rocks (especially coal) and solution-mining of salt. Slower local subsidence may also be induced by: fluid withdrawal (gas, oil, groundwater, geothermal fluids); densification or loss of mass in peat being developed for agriculture; drainage of surface waters from wetlands, which can cause oxidation, erosion and compaction of unconsolidated soils and sediments [see wetlands extent, structure and hydrology]; and filtration of surface water through porous sediments such as loess. On a much larger scale, the land surface elevation responds slowly to plate movements, compaction of sedimentary basins, and glacial rebound.

In tectonically active mountains, uplift may be as much as 20 mm/year. Although vertical crustal movements of continental platforms may range from less than 1 mm/1000 years, rates of 8-9 mm/year have been measured around Churchill, Manitoba, near the centre of the former Laurentide ice sheet. In California, groundwater pumping in the San Joaquin Valley between 1925 and 1967 led to land subsidence of up to 9 m, and oil withdrawal at Long Beach caused part of the city to subside 9.5 m. The outflow of geothermal fluids has caused up to 4.5 m subsidence at Wairaki, New Zealand. Surface subsidence due to sediment compaction in the Nile Delta ranges up to 50 mm/year, and parts of central California near the San Andreas fault have moved laterally as much as 3.2 cm/yr over the past two decades. Large-scale lateral movements of tectonic plates may average as much as 7 cm/year and more: the Pacific plate is now converging on the Tonga Ridge near Samoa at rates of up to 24 cm/year.

Fissures and faults can develop suddenly during earthquakes and as a result of volcanic processes and landsliding, or more slowly as a result of differential compaction during subsidence. In arid and semi-arid terrains, fissures up to several km long and a few cm wide may be rapidly eroded by surface run-off to gullies, some as much as 1-2 m wide and 2-3 m deep. In China, surface cracks due to fault growth have been observed to extend laterally at rates well over 100 m per year. In the USA, surface fault scarps have been noted up to 16 km long and 1 m or more high, growing vertically by aseismic creep at rates up to 60 mm/yr. Regional shortening of 15 cm over a distance of 50 km was measured in Japan prior to an earthquake in April, 1995, following which the shortened distance returned to normal.

Significance: Most Surface Displacements Have But Minor Effects On Landscapes And Ecosystems. However, there are exceptions, such as where drainage channels are suddenly displaced by faults, or where seismically-induced uplift raises intertidal ecosystems above sea-level. Moreover, extraction of fluids beneath urban areas can induce land subsidence (as in Bangkok, Mexico City, Shanghai, and Venice) and cause flooding, especially of coastal communities near sea-level. Subsidence damages buildings, foundations and other built structures: in the Houston-Galveston area of Texas, movements on more than 80 surface faults due to regional subsidence have caused millions of dollars of property damage.

Environment where Applicable: Tectonically active areas (active fault zones, areas of high seismicity), areas formerly covered by ice sheets, and areas where subsurface fluids are being withdrawn.

Types of Monitoring Sites: Active fault zones, reservoirs, coastal communities, deltas, urban areas extracting groundwater, oil or gas.

Method of Measurement: Repeated precise levelling and ground surveys, gravity determinations, and in coastal zones tide-gauge records. Standard geodetic techniques, especially using GPS and laser range finders. Archaeological studies of former coastal settlements now below or substantially above sea level.

Frequency of Measurement: Depends on the movement taking place

Limitations of Data and Monitoring: The sudden collapse of the ground surface in karst terrain or above mined cavities, and surface movements due to earthquake faulting are not generally predictable.

Possible Thresholds: NA

Key References:

Holzer, T.L. (ed) 1984. Man-induced land subsidence. Boulder, CO: Geological Society of America, Reviews in Engineering Geology VI.

Johnson, A.I. (ed) 1991. Land subsidence. Proceedings of 4th International Symposium on Land Subsidence. International Association of Hydrological Sciences Publication 200.

National Research Council 1986. Active Tectonics. National Academy Press, Washington.

Related Environmental and Geological Issues: Surface flooding in subsiding areas, damage to built structures, changes to hydrological systems. Rapid, warping of the ground surface may be a sign of impending sudden stress release, a precursor of an earthquake or, in an area of active volcanicity, an eruption.

Overall Assessment: Displacements of the ground surface can be used to assess and warn of environmental problems, especially in coastal areas and in areas liable to subsidence from bedrock solution, mining and fluid extraction.

Source: This summary of monitoring parameters has been adapted from the Geoindicator Checklist developed by the International Union of Geological Sciences through its Commission on Geological Sciences for Environmental Planning. Geoindicators include 27 earth system processes and phenomena that are liable to change in less than a century in magnitude, direction, or rate to an extent that may be significant for environmental sustainability and ecological health. Geoindicators were developed as tools to assist in integrated assessments of natural environments and ecosystems, as well as for state-of-the-environment reporting. Some general references useful for many geoindicators are listed here:

Berger, A.R. & W.J.Iams (eds.) 1996. Geoindicators: assessing rapid environmental change in earth systems. Rotterdam: Balkema. The scientific and policy background to geoindicators, including the first formal publication of the geoindicator checklist.

Goudie, A. 1990. Geomorphological techniques. Second Edition. London: Allen & Unwin. A comprehensive review of techniques that have been employed in studies of drainage basins, rivers, hillslopes, glaciers and other landforms.

Gregory, K.J. & D.E.Walling (eds) 1987. Human activity and environmental processes. New York: John Wiley. Precipitation; hydrological, coastal and ocean processes; lacustrine systems; slopes and weathering; river channels; permafrost; land subsidence; soil profiles, erosion and conservation; impacts on vegetation and animals; desertification.

Nuhfer, E.B., R.J.Proctor & P.H.Moser 1993. The citizens' guide to geologic hazards. American Institute for Professional Geologists (7828 Vance Drive, Ste 103, Arvada CO 80003, USA). A very useful summary of a wide range of natural hazards.